White Paper

Packaging and dilemmas in packaging development

By Professor Roland ten Klooster

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Over 3.5 billion are lost to the cost of packaging, packaging should add value and not be seen as waste', says Professor ten Klooster.

Better packaging can lead to a better product, he claims, which is why he suggests revising and professionalizing the development processes.

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Packaging designer and problem solver, appointed as Professor Packaging Design and Management at the University of Twente

Content

1 Introduction

Everybody has an opinion about packaging. It's like football, everyone's an expert! Its association with environmental problems is often heard. Unfortunately, there are few people who know the ins and outs of packaging. Looking at packaging without looking at the product it protects is pointless. Product and packaging go hand in hand and need to be analysed together. The development of a product has to be in tandem with the development of the packaging. In this paper the issue of packaging will be introduced and discussed, and packaging will be given the place it deserves.

2 Key figures about packaging

The average person opens 7 packed products a day, which translates into 140,000 packs over an average lifetime. 43 billion packs are opened every year in the Netherlands alone. Estimates of the European Community indicate 25,000 packs are opened every second. At an average weight of 25 gram, (1) this is 37,500 kg a minute!

Some people claim that the amount of packaging is increasing slowly. Cultural and demographic developments, knowledge of other cultures, the wish for fresher products and more variety in taste influence the amount of packaging. People hardly have any idea of numbers in the so called 'World of Packaging'. Over one million bags of crisps, regular taste, are sold every week. If there's football on television, more than three million bottles of beer may be opened. The average speed of filling equipment is 60 a minute. Fillers of cans of beer can do more than 90,000 cans per hour. It is clear that standardization is important in this part of business.

About 38% of packaging is plastic, 35% is fibre based material (paper, board, corrugated board, pulp), 12% is metal and about 10% is glass. The rest, about 5%, is wood (pallets and boxes), jute, cotton, biologically degradable materials (starch, polylactides) and others. Worldwide about 66% of packaging materials is used for food. In Western countries this figure is slightly lower and is estimated at 60%. In countries where food protection is important, more food is being thrown away, strangely enough, because of bad packaging and a lower state of technology.

3 What is packaging?

It is strange that no proper definition of packaging exists. What is packaging in fact? Is the layer of grease on a car before transport on a truck packaging? Is an empty soap dispenser packaging? We will go into more detail.

3.1 Definition

Paine[2, 3] wrote several manuals on packaging and says that *"the basic functions of packaging are for the purpose of product identification and the product's safe delivery through the distribution channel to the end-user"*. In his manuals, Paine even uses several definitions of packaging. He has different approaches and defines packaging from several viewpoints such as:

- a co-ordinated system for the delivery of goods through the chain and to enable them to be used;
- a means of ensuring that the product is delivered safely and in good condition to the end-user at minimum of cost;
- a techno-economic function in optimizing the cost of delivering goods at maximum return and profit.

The European Commission (94/62 EC) defines packaging as; *"everything that is being used for containment, protection, handling, delivery and presentation of goods, is packaging"*.

In a broad study about packaging functions Ten Klooster[4] comes up with the following definition of packaging: *"Packaging is the fulfiller of functions that is added to a product to bridge the aspects of time and distance at acceptable cost and acceptable environmental impact, ensuring acceptable quality of the product for the end user"*. Many questions can be raised about this definition (as with most definitions).

- What exactly is acceptable quality, cost and environmental impact?
- Who is the end user?
- What does bridging time and distance concern?

If someone buys a bottle of perfume, the packaging needs to enhance the feeling that he or she bought something special, even if it is only to justify the amount of money that has been spent. The cardboard box of an Apple computer is printed in beautiful colours, a cardboard box of a Dell or Compaq computer is brown. Gerkens cacao for example uses white paper bags for their industrial packaging (20 or 25 kg) to underline the feeling their cacao is of high quality. Cacao is sensitive to Salmonella and the cleaner the packaging the better. A brown paper bag camouflages spillage and therefore a white paper bag underlines the clean way of working.

These examples show that packaging is more than just the protection of the product. Packaging is used as 'the silent salesman', a statement often used, not only for retail packaging, but also for industrial packaging as the examples show. This means it is not only what the packaging should do, but also, how this is executed, two sides of the same coin. The printed

box and the brown box both protect computers. The presentation of the boxes is different and shows that emotional functions also play a role in purchasing products or in the perception afterwards. The model presented in the figure makes a distinction between the so-called more tactical based functions and the more strategic based functions.

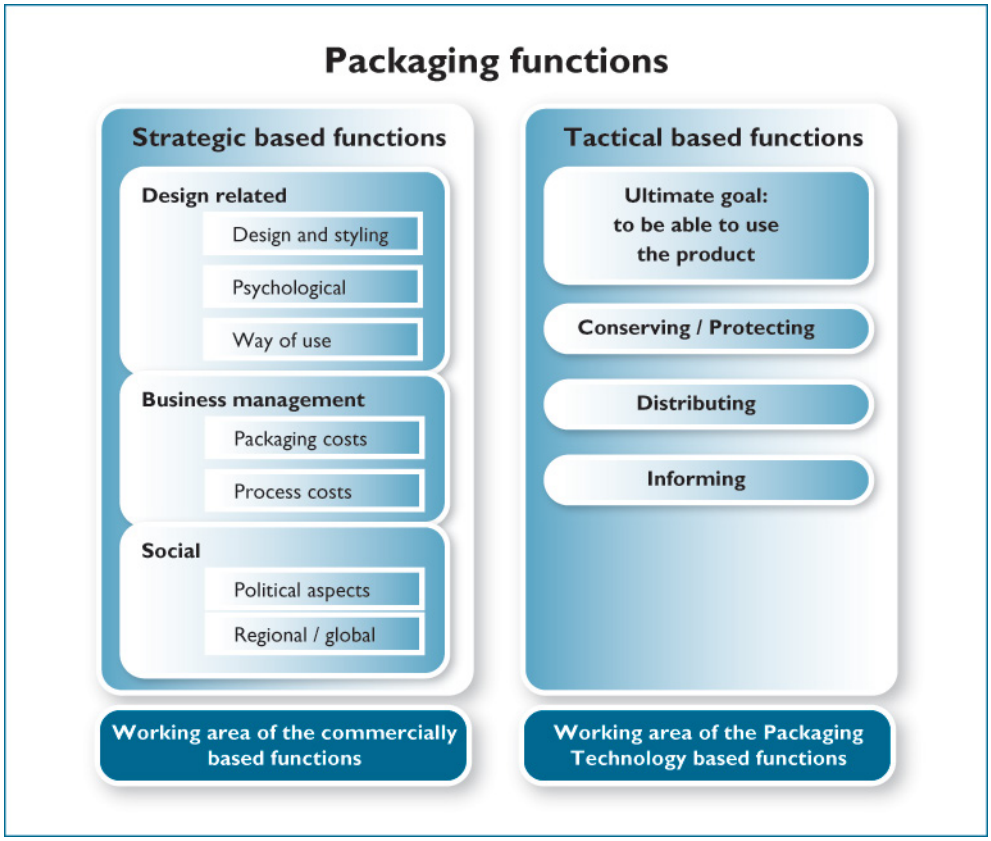

Figure – Model to present functions of packaging

3.2 Basic functions

The main functions of packaging are:

- Protection or conservation of the product
- Distribution of the product from producer or merchandiser to buyer
- Information to the many users in the chain about needed or wanted aspects.

These will be set out first, and then the other aspects of the definition are picked up again.

Protection

To protect the product it is necessary to understand the vulnerabilities of the product. There are five categories of vulnerabilities. In the table the vulnerabilities, an explanation and examples are provided.

Vulnerability	Explanation	Examples	Remarks
Biological	Micro-organisms (bacteria, yeast, fungi)	Food, medicine	Water activity plays and important role
Biochemical	Enzymes being active	Meat, fruit and vegetables, soap with added enzymes	Humidity is important to activate enzymes
Chemical	Reactions with oxygen or other reactions	Vitamins, fats, flavours	Oxygen causes most deterioration of products
Physical	Drying, wetting, UV-light, tainting (taking up odours out of the surrounding), melting, static charge	Humidification of biscuits and crisps, drying of tobacco, breaking down vitamins by UV-light (riboflamines), fatty products such as chocolate taking up the odour of the surrounding, integrated circuits of electronic equipment can be damages, etc.	Complicated group of aspects which can influence each other and which are influenced by reactions of oxygen
Mechanical	Shocks, vibrations	Breaking, tearing, bumping by falling or by vibration of transportation mean	The vulnerability is defined in g-values (number of time the product can carry its own weight

Many people do not understand the so called 'date of consumption'. There is a difference between very delicate products, perishable within five days and products with a date until when the quality of the product is guaranteed. And that is just the point; the quality is guaranteed to the specified date. It means the product no longer meets the quality standard of the company anymore after this date, but in most occasions it can be consumed without any problem. Quality loss of most products means that the taste is not what it should be, according to the company. Most people are used to consuming products with an oxidized taste, such as coffee, oils, many dairy products such as milk, etc.

Figure – several ways to present the date of consumptions make it more confusing

Spoilage of products, especially food is tremendous. It is estimated that 15% of all food is not consumed. It is thrown away, over dated, damaged, quality loss in the chain (fungi are visible, the taste is not okay, too dry, too soft, etc.), not trusted anymore by the consumer. There also a lot of spoilage at restaurants and all kinds of food centres because demand and offer do not match. About 7% of medicines used in hospitals is thrown away. About 2% of cars are damaged during transport. Estimates of damaged durables are between 0.1 and 1.0%. In the Netherlands it is estimated that the total value of products thrown away is over 5 billion euro which is more than the total amount of money spent on packaging!

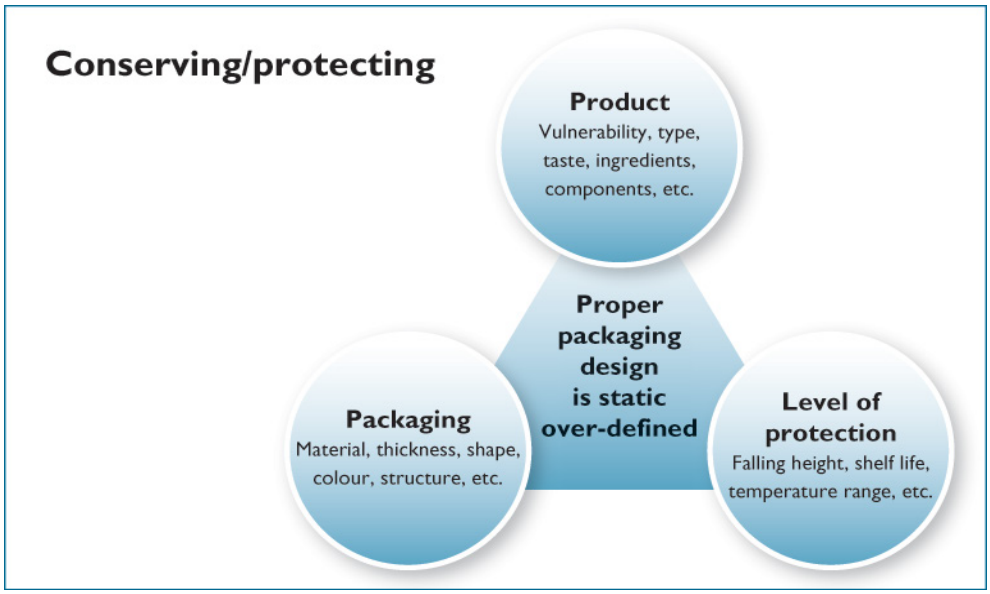

Figure – every product has its own vulnerabilities which have to be in line with the needed or wanted protection defined by the packaging

The abovementioned packaging functions account for every product that is being packed. Nevertheless, there is a big difference between the kinds of products that are being packed. Food has completely different vulnerabilities than, let's say, durables. The overview in the table gives an idea of the aspects that are important when developing packaging for a certain kind of product.

	Biological	Biochemical	Chemical	Physical	Mechanical
Food	Growth of micro organisms	Enzymes becoming active	Reactions with oxygen	Drying, wetting, UV-light, tainting	Shocks and vibrations
Medicine	Will be similar to food or even more strict, but the process is more important because a small mistake could prevent people from curing or cause death. Therefore Good Manufacturing Practice (GMP) is being used.				
Non-food non-durable					Shocks and vibrations, static charge
Industrial packaging	Depends on the type of product, can be the same as food.				
Dangerous goods	Legislation: protecting the surrounding from the product. The packaging must be able to withstand different kind of forces, depending on the type of danger. The packaging must be tested for UN-marking and must contain information about the kind of danger (like symbols). Possibly tests about interaction between packaging and product have to be carried out. For powders static charge is important as well.				

Distribution

How can we get our products to the right place on time against acceptable costs? That's the main question of the distribution function of packaging. A system was introduced in the Netherlands to optimize transport means.

The width of a truck was the starting point and pallets are dimensioned with these figures in mind. The so-called Collomodule System is very strong and is spreading over Europe. The basic dimension of this system is 400 x 600 mm, which allows the most used pallets (nowadays) of 800 x 1200 (known as Euro pallet) and 1000 x 1200 mm to be optimized. All crates for vegetables, beer, beverages, etc. are therefore 400 x 600 or 300 x 400 or 200 x 300 mm. Smaller dimensions are acceptable, but have to fit in the basic dimension without loss of pallet space. Roll containers, so-called rollies and dollies are all dimensioned based on the Collomodule System.

This system has become a standard within ten years. First, food was changed, and later non-food was optimized. And changes are still going on. Depending on the kind of products or standardized packaging, dimensions and transport means can differ from the Collomodule System. Tetra packs and vacuum coffee packs do not fit in this system. It would cost more to change the dimensions of the packaging than you save on transport. Another problem is that shipping containers have outside boundaries of 242 cm, which is the same as the inside boundaries of Dutch transport trucks. This means that what fits into the Collomodule System, does not fit into shipping containers.

Information

All kinds of information can be found on packaging. The printer wants to see the spot marks, the filler likes to see machine spots, the distribution channel likes to see barcodes or figures, the user needs information about the brand, how to use and open the packaging, about storing, re-closing, etc. and at the end it must be clear how and/or where to throw it away. Printing technique is a field with its own knowledge and expertise. Many designers who make graphic designs for packaging do not have any knowledge of the printing process and on many occasions their designs are not the best options for the process. Taking the process into account makes it even more complex. This can present production with questions such as: how to put a label on packaging in such a way that a line on the label is exactly in line with an embossed area on the packaging. Or, how to control the colour between the spots on the label and be sure they are the same as the colour of the cap produced with injection moulding?

The functions of packaging will be set out shortly. These functions account for all kinds of packaging. This part of the business is managed chiefly by packaging technologists or people with some technical background. Education in this field of business is not on the level it should be, which is part of the reason why so many products spoil. How these tactical functions are executed differs greatly. Let's take a look at the more strategic based functions.

3.3 Strategic based functions

The more strategic based functions can be split up in three sectors. The first concerns the design related aspects of packaging. The shape of the packaging can tell something about the product it contains. With colour, graphic elements, fonts, pictures and logos or names, packaging can be designed to be attractive to the buyer or user. Coca Cola designed its bottle many years ago and the bottle is an example of a packaging which became an icon.

1916 … Birth of the contour bottle

Bottlers worried that the straight-sided Coca-Cola bottle was easily confused with imitators. A group representing the Company and bottlers asked glass manufacturers to offer ideas for a distinctive bottle. A design from the Root Glass Company of Terre Haute, Indiana won enthusiastic approval in 1915 and was introduced in 1916. The contour bottle became one of the few packages ever granted trademark status by the U.S. Patent Office. Today, it's one of the most recognized icons in the world - even in the dark!

Source: www.thecoca-colacompany.com

The influence of details in design and styling is huge. A font that does not fit the shape or colour can affect sales and also the opinion of the buyer on the quality of the product. This field of packaging design is still under development. Many companies try to get a grip on the consumer's perception. With which design is the consumer content and will he/she buy my product? The question is simple, the answer is complex. Besides design and styling related aspects, it is also important how the packaging has to be used. The way the packaging functions has to belong to the perception of the user as well. A good example is a soap pump. To wash your hands, you can use a piece of soap. It is cheap, easy, although it messes up the soap dish. A pump filled with liquid soap is more expensive, but if works so much better that hardly anyone still uses a piece of soap. The same accounts for many other concepts, for example the Senseo coffee machine which completely changed the way we make coffee.

Picking up, holding, opening, pouring, re-closing, putting away, knowing what the contents is, just a list of functions related to how packaging is handled. This also accounts for industrial packaging and small and big containers, intermediate bulk containers (IBCs), big bags (Flexible IBCs or FIBCs), etc. A company can influence sales by designing packaging that is easy to use and gives the user a reliable or good feeling.

Business management is about turnover and profits. How much may the packaging cost? Not easy to tell beforehand, it depends on the functions the packaging fulfils. Besides that, the market of the product is also very important. A key figure to get some insight in possible packaging costs is the sales value on the pallet (or a full truck, if no pallets are used). If the whole pallet contains just a few thousand euro, there will be not much room to design expensive and shiny packaging. If the pallet contains thousands or even hundreds of thousands of euro, than packaging may cost more. The costs of the packaging for perfume may be much higher than the costs for a jar for marmalade. The packaging process is strongly influenced by the packaging design. A cheap product has to run efficiently over the packaging line, an expensive product has more room in processing costs. Design and engineering detail the costs of the packaging strongly and have to be included at an early stage. Mind you, packaging materials belong to the cheapest materials used in Western countries.

Social aspects can influence packaging design in several ways. Legislation is enforcing. If the word 'verpakken' (packaging in Dutch) is typed on the website wetten.nl (an overview of Dutch legislation) about 300 references can be found. All these references should be checked, before going to the market. Legislation is increasingly becoming a European matter, which makes it easier to export, but also more complex because all the differences have to be studied over again. Environmental aspects are important because of our concern for the influence of consumption, way of living, etc. on our planet. Since Al Gore's movie, the carbon footprint (CFT) has become an important aspect in product and packaging design.

4 The packaging development process

The packaging development process needs to be managed. The strategic functions have to be met and attention has to be paid to the tactical functions. Vulnerabilities of the product to be packed have to be defined and the distribution chain has to be known. The graphic design has to be made and needs to be adjusted to the packaging material and printing process. Many of these aspects are detailed by the packaging chain. On many occasions the packaging chain has many links. It is not always known what requirements have to be formulated for every step of the chain because the package handling has not been defined. This means that uncertainty is part of the design process. The number of links in the chain also has another consequence in that requirements can be conflicting. The number of totally different aspects, the fact that requirements can conflict, the fact that details can influence the packaging process; all these aspects show that packaging has to be managed professionally. Plenty of reasons to go into this process in more detail.

4.1 Packaging chain

The packaging, empty before filling, filled, empty after filling, goes through a chain comprising several links. Analysing the chain is not easy either. The links in the chain may demand totally different requirements from the packaging. When packaging is used as returnable packaging, the chain becomes even longer with more specific requirements about the return transport and about cleaning. The following list shows what is required of industrial packaging (not exhaustive).

Example of a list of industrial packaging requirements

Concerning protection

- The packaging has to protect the product, in all parts of the chain
- The packaging has to be tamper-evident (to show that nobody else has opened it before)
- The product inside the packaging may not interact with the packaging material
- For food: the packaging material must be food grade
- The packaging must protect the product against reaction with oxygen (must have a proper barrier against gasses)

Concerning filling

- It must be possible to clean the packaging and/or check that the packaging is clean
- It must be possible to sterilize the product after filling

Concerning use

- It must be possible to open the packaging safely
- It must be possible to open the packaging easily with little handling

Example of a list of industrial packaging requirements (cont.)

- It must be possible to re-seal the packaging
- The packed amount must be fit for the purpose
- If powders are packed, the container may not attract the powder by static charge

Concerning distribution

- The packaging must be stackable
- It must be possible to stack the packaging two pallets high
- Empty packaging must be nestable

Concerning informing

- The packaging must indicate which product is inside
- The packaging must provide information about the sender, the amount, etc
- The packaging must indicate the shelf life

Packing of dangerous goods

- The packaging must tell the user if the product is safe or how to handle the product
- The packaging must contain symbols required by law, for example UN marking

Concerning costs

- The packaging may not cost too much (value for money).

Concerning environment

- The packaging may not lead to unnecessary pollution.

Packaging of pharmaceutical products

- Production of the packaging and the packaging process must meet the rules of Good Manufacturing Practice (GMP)

The list of requirements shows completely different aspects that have to be combined in a packaging design. Aspects concerning design and styling are not even taken into account. The package has to protect the product and needs to be strong enough to carry the load through the distribution chain. It also needs to be stackable, but you should also be able to open it easily. The information must be legible, and the costs and the environmental impact must be at an acceptable level.

The packaging chain with all the different links requires a proper analysis to meet all the requirements. A small mistake can have a huge impact, for example loss of quality and useless medicine or product recalls. Below is an example to prove how complicated a packaging design can be.

Calculations required to unscrew a metal cap[5, 6] show that reducing the force will conflict with safety and product protection issues as well as the number of turns necessary to unscrew the cap, which is a convenience issue. This is illustrated in the figure.

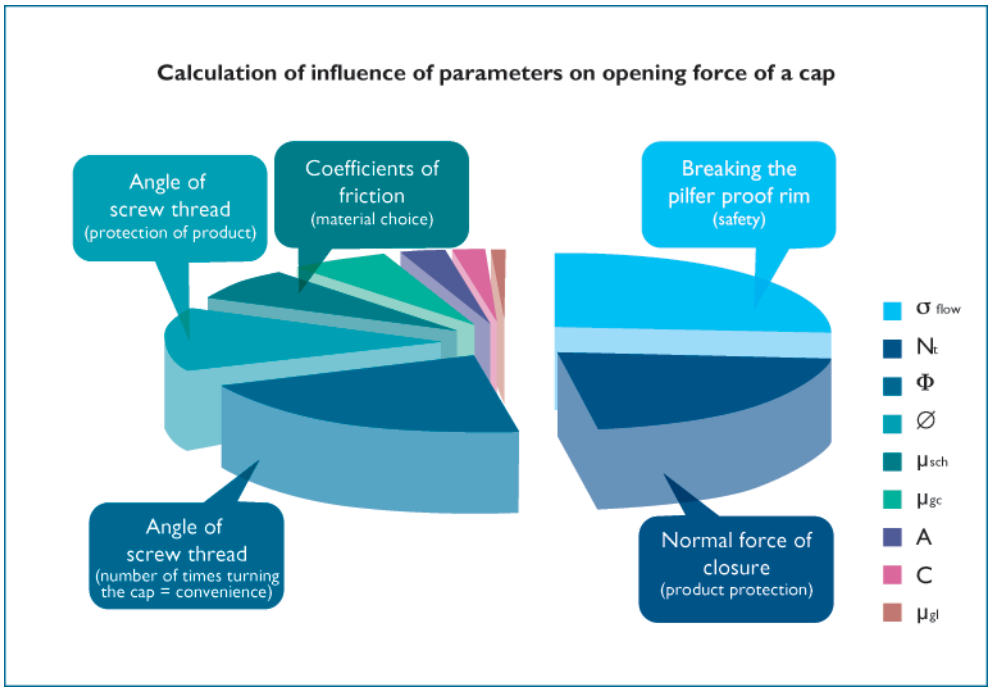

Figure – Forces needed for opening a metal cap in relation to packaging requirements

The level of professionalism in the packaging sector is quite low, compared with the total turnover. This statement is not aimed at the people working in this sector, but at the attention companies, NGOs and governmental organizations pay to packaging. Hardly any attention is paid to packaging at schools and many companies approach packaging during the latest stage of the product development and process, which is usually too late to find good or optimal solutions for the conflicting requirements. The position of packaging technology inside a company is not always as it should be, taking into account the possible consequences. Packaging needs management.

4.2 Decision process

The decision process of a product-packaging combination starts with the market. The need, hard to define nowadays, is analysed by marketers, who come up with ideas to change the product and/or packaging or to introduce a new product. In other words, product and packaging designers are asked to design the product and the packaging. We already stated this should be done in co-operation and with interaction. Product designers and packaging designers have different backgrounds and totally different approaches to the design process, which requires good management. After the product and the packaging have been designed, the process to produce the packaging and to fill the packaging has to be organised. This field of knowledge is not yet mature either. A few guidelines can be used but the link between the packaging design and the expected overall equipment effectiveness (OEE) has still not been filled in. This means that it is hard to communicate with all parties working on the packaging line and to obtain any guarantees about the expected output of the line.

Figure – The relation between packaging line and OEE of the packaging line is still a blank field

After the design and engineering process, a decision can be made about the investments. If accepted, the implementation of the project can start.
In projects where mistakes have been made, going back to the process management to discuss the whole matter is not an option. And talking to the product and packaging designers to change the product or packaging is practically impossible. We don't have to talk about going back to marketing to say the idea was not that good. This description shows that a multi-disciplinary team is required to launch a new product development and/or packaging. Aspects that have not been mentioned in the description, such as purchasing, people management, the quality of the equipment, also affect the output. Describing the whole process would cost many more pages. It is clear that the process is a lot more complex than described in this paper.

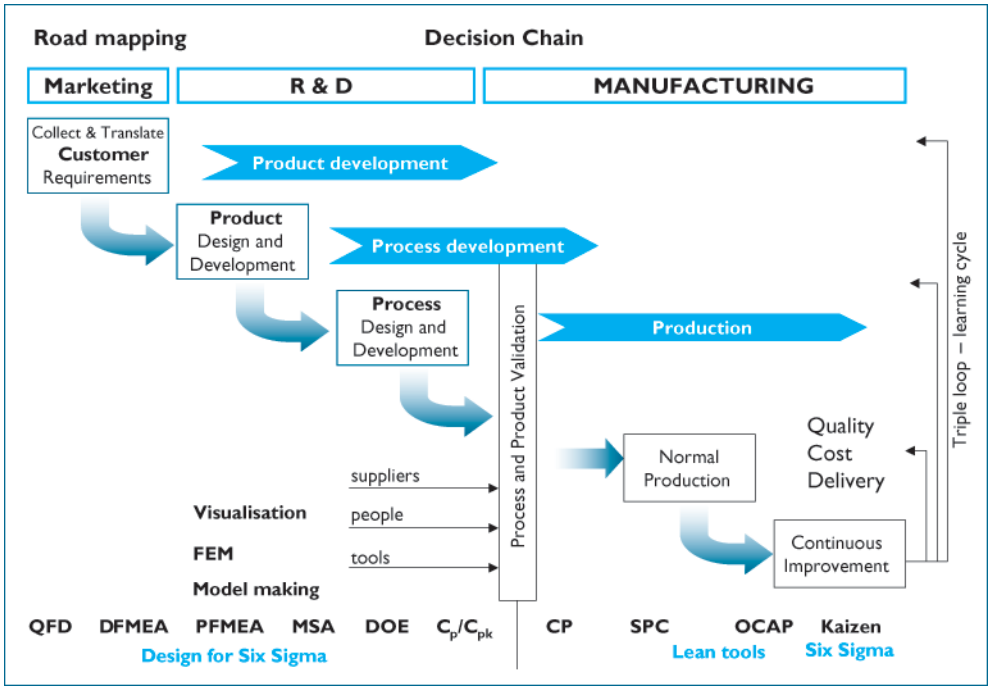

Figure – The decision process (schematic overview)

In the decision chain abbreviation of tools are taken up. These tools can be used to optimize the decision process of the packaging design from marketing to production. They include Quality Function Deployment (QFD), Failure Mode Effect Analysis (FMEA, design and process), Statistical Process Control (SPC), Design of Experiment (DOE), Six Sigma, Kaizen. The decision process shows lines which go back into the process to optimize the solution. It is clear that this process needs professional management.

4.3 Down to earth

In practice, packaging design is often underestimated. The description provided in this paper shows that many different aspects have to be taken into account during the packaging design process. So-called earthly problems often occur. For example:

- 7 colour designs for a 6 colour printing machine
- graphic detail design for 4 colour flexo print on plastic film
- bowls that do not fit into standardized crates
- products that should not come into contact with the packaging material (low density polyethylene does not go with many natural oils, a combination which often occurs in food packaging and causes problems or even recalls)
- products that break during the filling process
- graphic information that has to be put on packaging in the packaging process in a way that is technically not feasible without loss of efficiency (for example a lined label design that has to line up with details in the contour of the packaging design)
- pallets that collapse because the stacking height in the chain is higher the starting point

Figure – a nice graphical design does not look nice after filling because the potatoes look green

The examples show that details can influence the development process. That is why this field of knowledge is often seen as expert knowledge. It explains why packaging design requires people to co-operate in every link of the chain. Of course, many people are afraid to ask a supplier for advice because he is part of the deal. Nevertheless, technical support can be of great value. A way to overcome this is to work with functional specifications, in addition to the technical specifications. A functional specification describes what the packaging is expected to do, on which packaging line it has to run, in which chain it has to function, etc. This document can help to overcome mistakes and can help to optimize the relation between producer and supplier.

4.4 Packaging and the environment

Primarily, packaging should protect the product. We already explained more products are thrown away than is spent on packaging. The packaging must bring the product to the user and guarantee the quality of the product. When the packaging chain is known, the packaging design can be optimized. This requires engineering within all the constraints taken up in the design. In practice this means that the same aspects have to be involved in this process. For most packaging, optimization is hardly possible because of the short time it is available before being replaced by something else. Standardization is therefore an important tool, but conflicts with the desire to be different from the competition.

However, if a product is thrown away, more is thrown away than is visible to the naked eye. The whole production process with all the energy and emissions is also important. Life cycle analyses of needs in the market (for example the need to wash clothes) show that the packaging is only a very small part in the environmental load. This is in line with the estimated amount of rubbage related to packaging: less than 3% of the total amount. The same accounts for other environmental problems. Packaging contributes less than 3% to these problems as well. Still enough to take the engineering, material choice, amount of space, etc. into account. As calculations (2008) on the use of coffee cups showed us, this has to be done with special care. Despite what we would normally think, disposable coffee cups are better for the environment than washable porcelain coffee cups.

Several measures based on reducing the environmental load seem to forget the most important function of packaging: protection of the product. It is very hard to understand how packaging functions and why several layers or more polluting materials are required. However, this should be the reason to leave the most important part of the chain out of the analysis.

5 Conclusions and recommendations

Packaging is more complex than many people think. Many companies have the same attitude. This paper showed many of the aspects that have to be taken into account when designing or developing packaging. The dilemmas in packaging development can be formulated as follows:

- Packaging needs professional management
- Packaging has to contribute to how products are distributed in a chain with unknown load and at the same time guarantee the quality of the product
- Packaging design and development are subject to tight time constraints making it impossible to produce quality packaging
- Packaging is a field of expert knowledge in which detail can seriously affect the process
- Requirements in packaging design often conflict and choices need to be made carefully
- Packaging design is important in terms of environmental issues: the products are more polluting than the packaging

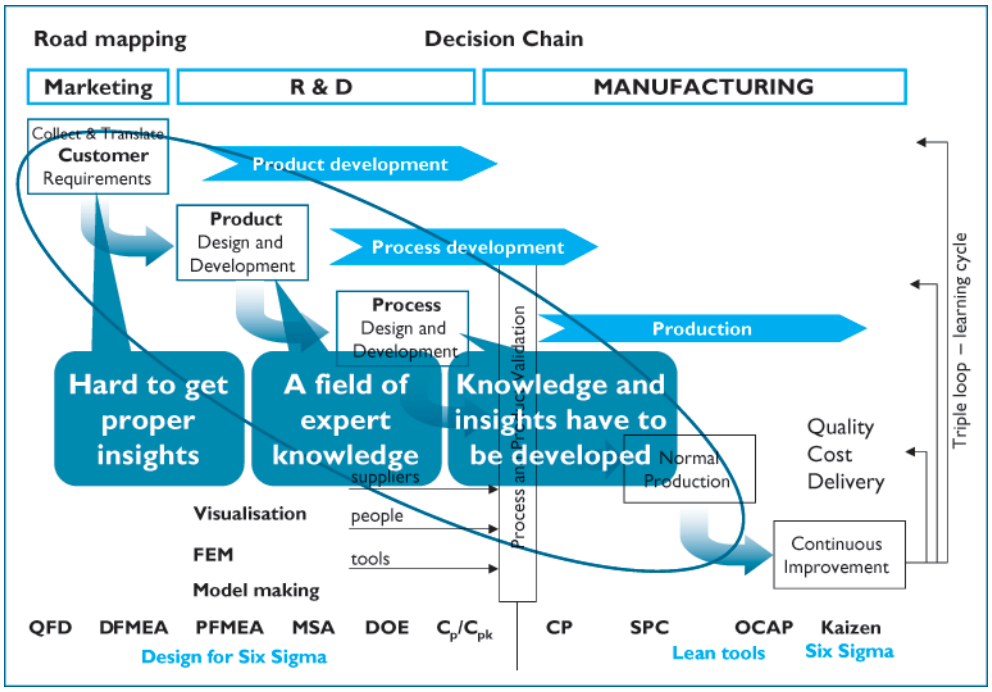

Figure – the decision process with the dilemmas

This paper aims to create a mature part of business: packaging.

Delft, 31 March 2008
Roland ten Klooster

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